EFFECT OF PROCESS PARAMETERS ON RECOVERY BEHAVIOUR OF POLYESTER-COTTON BLENDED ELI-TWIST AND TFO YARNS

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Abstract:

The relationship between magnitude of instrumental measurement of the elastic recovery properties and some yarn parameters has been studied. As compared to Eli-Twist yarns, TFO yarns are better in terms of recovery characteristics. In general, yarns with high polyester content in the fibre mix having higher immediate elastic recovery and lower permanent deformation. High amplitude of extension reduces the immediate elastic recovery and delayed elastic recovery. Coarser yarns have high immediate elastic recovery and low permanent deformation.

Key words: Delayed elastic recovery, Eli-Twist yarn, Immediate elastic recovery, Permanent deformation

1. INTRODUCTION

Spinning is a process in which, fibres are drawn out and twisted together to form a yarn. With the growing demand, lot of technological changes took place. The production in initial days was very low. Increased interest of industry people in high production speed and stringent quality requirement led to the development of many new spinning systems. Presently, ring spinning is the most widely used yarn production method for its flexibility in terms of spinning limit and yarn quality. Lot of modifications took place in ring spinning system to improve the production as well as the quality of yarn.

Single yarns are plied to attain particular physical characteristics and mechanical property that cannot be obtained with a single yarn of similar count. A plied yarn is produced by twisting two or more single yarns together. Additional assembly winding and twisting processes make the ply yarn production expensive than the equivalent single yarn. Eli-Twist yarns are basically compact ring double yarns, in which doubling takes place in the ring frame and yarn is single wound. The technology is developed and perfected by Suessen Corporation. It combines compact spinning and doubling of a yarn in one single operation. In this process, two roving passes through the twin condensers at the entrance of the drafting system and drafted separately at certain distance. At the front roller nipping line of drafting system, two fibre strands are joined in a V-shaped arrangement. From there, the twist imparted by spindle spreads into the two yarn legs and about 80% of twist produced by a spindle gets into the individual leg of yarn [1]. It produces a two-ply yarn with identical direction of twist in both yarn legs. It leads to a very smooth structure of yarn, closed yarn surface and circular yarn cross-section. The yarn has a high regularity. It has an extremely low hairiness, especially of long fibres. The yarn has very high breaking load and elongation and very low pilling tendency [2]. It lends itself easily to splicing. Most suitable process parameters for a better quality Eli-Twist yarn are 8 mm distance between the drafted fibre strand and 24 mbar negative pressure in suction tube [3].

The mechanical properties of spun yarns are dependent on their structure, properties of raw materials and process parameters used. In most of applications and product conversion processes (weaving/knitting) yarns are subjected to stress, especially elongation of low magnitude. Even during the course of handling, yarns experience repeated small strains and are also subjected to rupture under high stress. The ability of yarns to recovery from strains below the breaking point makes it suitable for further mechanical processing. Thus, the elastic recovery and its variability is becoming an increasingly important factor for adequate functioning of yarns during applications and for long-term storage. The elastic recovery of textile material, a time-dependent phenomenon, plays a special role as one of the mechanical properties [4]. Although a single stress-strain curve taken from zero strain to rupture provides much useful information, but it does not tell anything about the recovery properties of yarn. By carrying out cyclic loading and unloading, the recovery properties of a yarn can be assessed. Recovery of textile material is not only dependent on its structure but also on the magnitude, rate and duration of applied stress or strain. The longer it is held at a given extension, the lower is the level of recovery [5, 6]. While the rate of extension and its magnitude also influence the elastic recovery and permanent deformation behavior [7]. Stresses and/or strains of repetitive nature applied on a textile product may cause delayed elastic and plastic aftereffects. Different studies are available on elastic recovery of ring spun, rotor spun, air jet spun and MJS yarns [7-12]. In the present study, an attempt has been made to study the effect of fibre composition, yarn linear density and amplitude of extension on the recovery characteristics of Eli-Twist yarn. To identify new application areas for Eli-Twist yarn a comparative assessment of recovery properties is carried out with conventional TFO yarn.

2. MATERIALS AND METHODS

2.1 Material

39.36 (2×19.68) Tex, 29.52 (2×14.76) Tex and 23.62 (2×11.81) Tex yarns were spun from polyester, cotton and their blends on Eli-Twist spinning and conventional TFO machines. The fibres specifications are given in Table 1. For blending, combed cotton fleece was mixed with polyester at blow room. The conversion to carded sliver was carried out by using LC100 carding machine. The carded slivers were drawn on DO/6S. For 100% cotton and its different blends with polyester two passage of drawing were given whereas, for 100% polyester, the substrates were drawn thrice under identical processing conditions. The Eli Twist yarn samples were prepared on ring frame LR60/AX with Elite Compact Set by Suessen keeping the Tex twist factor constant (40 tpc × $tex^{½}$). The single ring yarns were spun on Lakshmi Rieters' ring frame G5/1 and doubled on Saurer compact twist by Volkmann VTS 09 TFO machine with same twist factor as in Eli-Twist.

Table 1: Specification of fibres used

Fibre	Fineness (denier)	Fibre Length(mm)
Polyester	1.2 d	38

Cotton (H-4, 100%)	4.2 mic	30

2.2 Test Method

The recovery parameters of yarns were determined using a Zwick UTM tester according to ASTM D1774-79 procedure. Figure 1 shows the typical load vs. extension in an elastic recovery measurement [7-9, 12]. For each yarn sample 250 mm long specimen were elongated at an extension rate of 25 mm/min. The immediate elastic recovery (IER), the delayed elastic recovery (DER), and the permanent deformation (PD) were obtained for an initial extension level of 2% and 4%. For each selected level of extension, the yarns were allowed to fully retract and then relaxed for 3 min, and variations in extension were observed. Recovery components were calculated from the following expressions:

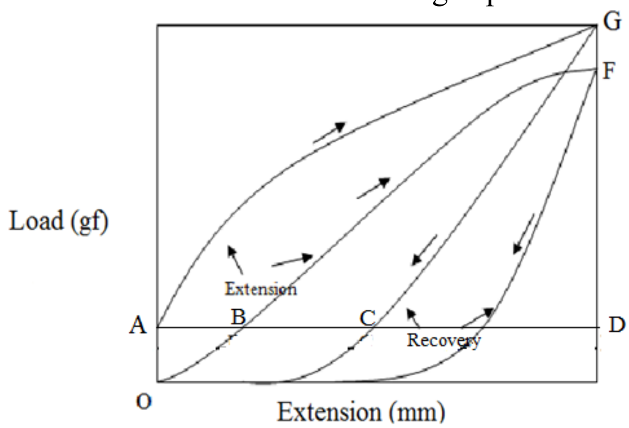

Figure 1: Extension cycling for evaluation of elastic recovery parameters.

$$\text{Immediate elastic recovery\%} = [CD / AD] \times 100$$

$$\text{Delayed elastic recovery \%} = [BC / AD] \times 100$$

$$\text{Permanent deformation \%} = [AB / AD] \times 100$$

3 RESULT AND DISCUSSION

Theory of extension in staple fibre yarn based on yarn failure

Staple fibre yarn being a visco-elastic material shows both partial elastic and plastic behaviour. When load is applied to a staple fibre yarn, the extension in yarn takes place in three different regions as follows:

- Region I: at initial stage of loading the increase in stress is proportional to strain. In this region the extension takes place due to straightening of fibres and/or slippage of fibres prevented by friction. Yarn behaves like perfectly elastic material.
- Region II: when stress is further increased slippage occurs at fibre ends. The magnitude of friction is maximum at the middle of fibre length and zero at fibre ends. The extension in this region occur due to partial slippage of fibre in the yarn at their ends as fibre are gripped tightly at the centre of its length.
- Region III: at higher stress both slippage and breakage of fibres occurs.

Theory of recovery from extension in staple fibre yarn

When load is removed from yarn the energy stored in fibres during extension got released and some amount of applied extension recovers immediately. Due to fibre cohesion the stored elastic energy of a fibre also help the neghbouring fibres to return their initial position and some amount of extension is recovered with time. When applied stress overcomes the fibre frictional forces fibre slippage and/or breakage occurs and an irreversible shift of fibres takes place. The change in yarn structure due to the energy loss during fibre slippage and/or breakage cannot be recovered at all and thus a part of extension remains there as permanent deformation.

Following factors may influence the extension and recovery behaviour of a yarn [12]:

- The mechanical property of constituent fibres
- Composition and arrangement of fibres in the yarn
- Frictional characteristics of the constituent fibres
- Fibre packing and hence compactness and inter-fibre cohesion
- Ability of structure to maintain its integrity
- Imperfections including shortfall in the required number of fibres

Elastic Recovery of staple fibre yarn

The experimental results for immediate elastic recovery, delayed elastic recovery and permanent deformation are given in Table 2. The influence of experimental variables, viz. yarn type, linear density, amplitude of extension and blend ratio on elastic recovery characteristics was assessed by using analysis of variance at 95% level of significance and the results are shown in Table 3. Only the first order interactions were considered in analysis. It is observed from the Table 3; the main factors have strong influence on yarn recovery properties. While most of the interaction effect of the factors on the yarn recovery are non-significant.

Table 2: Influence of linear density, blend ratio and amplitude of extension on recovery properties of polyester-cotton blended Eli-Twist and TFO yarns

Linear Density (Tex)	Blend Ratio	Immediate Elastic Recovery (%)				Delayed Elastic Recovery (%)				Permanent Deformation (%)			
		2[a]		4[a]		2[a]		4[a]		2[a]		4[a]	
		Eli-Twist	TFO	Eli-Twist	TFO	Eli-Twist	TFO	Eli-Twist	TFO	Eli-Twist	TFO	Eli-Twist	TFO
2×19.68	100/0 P/C	33.36	38.25	30	35.16	37.41	41.12	35.68	39.21	29.23	20.63	34.32	25.63
	80/20 P/C	30.93	37.4	26.48	33.62	38.99	41.57	37.36	39.58	30.08	21.03	36.16	26.8
	65/35 P/C	27.54	32.2	25.21	31.56	41.96	42.8	37.51	41.27	30.5	25	37.28	27.17
	50/50 P/C	25.42	31.91	20.12	30.29	37.72	42.45	41.54	41.33	36.86	25.64	38.34	28.38
	0/100 P/C	20.97	25	18.64	20.76	37.09	35.17	26.7	31.58	41.94	39.83	54.66	47.66
2×14.76	100/0 P/C	30.5	34.32	25.94	33.89	36.53	41.41	39.45	39.22	32.97	24.27	34.61	26.89
	80/20 P/C	29.23	33.05	22.03	31.17	36.66	41.64	41.38	41.06	34.11	25.31	36.59	27.77
	65/35 P/C	25.42	29.23	19.06	26.33	40.12	42.39	43.02	41.47	34.46	28.38	37.92	32.2
	50/50 P/C	23.3	28.51	18.64	21.79	41.99	39.79	41.41	43.17	34.71	31.7	39.95	35.04
	0/100 P/C	18.37	19.57	16.59	17.94	38.18	37.57	27.67	30.37	43.45	42.86	55.74	51.69
2×11.81	100/0 P/C	28.2	34.18	22.49	32.97	38.75	40.61	40.32	39.74	33.05	25.21	37.19	27.29
	80/20 P/C	22.1	32.55	20.24	27.63	43.58	42.03	41.75	42.08	34.32	25.42	38.01	30.29
	65/35 P/C	21.07	29.23	18.71	24.11	44.22	42.29	41.89	42.42	34.71	28.48	39.4	33.47
	50/50 P/C	20.66	24.15	17.58	20.72	42.36	41.11	38.99	40.73	36.98	34.74	43.43	38.55
	0/100 P/C	17.16	18.64	16.52	15.25	38.78	37.91	25.01	30.71	44.06	43.45	58.47	54.04

[a] Amplitude of extension (%)

Table 3: ANOVA test results

Process variables	F- ratio		
	Recovery properties		
	Immediate elastic recovery	Delayed Elastic Recovery	Permanent Deformation
A	192.60 (s)	8.83 (s)	397.38 (s)
B	71.68 (s)	3.15 (ns)	53.94 (s)
C	77.84 (s)	20.48 (s)	262.77 (s)
D	133.45 (s)	50.04 (s)	421.98 (s)
A*B	0.71 (ns)	1.73 (ns)	5.35 (s)
A*C	0.92 (ns)	0.43 (ns)	3.91 (s)
A*D	7.05 (s)	0.41 (ns)	9.50 (s)
B*C	0.34 (ns)	1.90 (ns)	1.46 (ns)
B*D	0.49 (ns)	0.61 (ns)	0.95 (ns)
C*D	0.75 (ns)	14.56 (s)	18.79 (s)

A- Yarn type; B- Linear density; C- Amplitude of extension; D- Blend ratio

s- Significant at 95% confidence level; ns- Non-significant at 95% confidence level

3.1 Immediate elastic recovery

An instantaneous extension of textile materials which recovered immediately on removal of load is referred as Immediate elastic recovery (IER).

Table 3 depicts the immediate elastic recovery of polyester-cotton blended doubled yarns spun on conventional TFO and newly commercialized Eli-Twist spinning system. The immediate elastic recovery value of bidirectional two-ply TFO yarn has been found more than that of unidirectional two ply Eli-Twist yarn. The lower immediate elastic recovery of Eli- Twist yarn is the result of high degree of compactness in the yarn structure which restricts the fibre movement in the yarn and hence the immediate elastic recovery. Furthermore, at same amplitude of extension immediate elastic recovery increases as the yarn becomes coarser, as a result of increase in the numbers of fibres in the yarn cross-section, due to which load borne by each fibre reduces and hence the possibility of immediate elastic recovery is high. While the immediate elastic recovery decreases as the amplitude of extension increases. At small extension small deformation due to fibre extension in yarn takes place which can be recovered after the load removal but higher extension leads to higher deformation as a result of fibre slippage and/or fibre breakage which may not be recovered immediately or the amount of immediately recovery will be less. Moreover, the immediate elastic recovery decreases as polyester content in the yarn reduces. The stored elastic energy is higher in polyester fibre as compared to cotton fibre. On the removal of load from the yarn polyester content tries to recover more and hence as the polyester content reduces the immediate elastic recovery also reduces.

3.2 Delayed elastic recovery

Table 3 also provides information on the influence of processing factors on the delayed elastic recovery of polyester-cotton blended Eli-Twist and TFO yarns. The delayed elastic recovery is observed to be noticeably higher for lower amplitude of extension. On looking at the results individually, it can be seen that the delayed elastic recovery, in general, is lower in case of Eli-Twist yarn than that of TFO yarn. The difference in the values of delayed elastic recovery is statistically significant. An obvious reason for the lower delayed elastic recovery of Eli-Twist yarn is the greater degree of compaction of the fibres in the yarn due to which structure integration is more likely to be dominated by fibre breakage. While relatively open structure of TFO yarn allows structure disintegration through fibre straightening followed by slippage and breakage. At low level stress, the openness of TFO yarn structure may help in recovery with time, on the other hand breakage being dominated in the Eli-Twist yarn. Moreover, up to a certain level delayed elastic recovery increases and then decreases as polyester content in the yarn reduces. Introduction of cotton content in the yarn reduces the compactness and structure becomes open. Polyester fibre has higher stored elastic energy and when the load is removed from the yarn the polyester component tries to recover and due to open structure it pull cotton fibres with it. It happens up to a certain level after that as the less extensible cotton content with higher bending rigidity increases it restricts the recovery from stress. Hence delayed elastic recovery initially increases and after certain level again decreases with reduction in polyester content.

3.3 Permanent deformation

Invariably, the permanent deformation appears to be higher for Eli-Twist yarns than for the TFO yarns. The rotational direction of spiral path followed by fibre in the single yarn and ply yarn is same for ETS yarn while it is opposite to each other in the single and final yarn in case of TFO yarn. Such a difference in the rotational direction of spiral path of fibres in TFO yarn produces inter-locking of fibres in the yarn which assist in recovery. Hence lower the permanent deformation. Increasing cotton component markedly continuously increase the permanent deformation regardless of yarn structure. Moreover, the coarser yarns display lower permanent deformation set and it substantially increases as amplitude of extension is increased from 2% to 4%. As the load share per fiber increases it leads to higher deformation.

4. CONCLUSION

All process variables, significantly affect the recovery properties of polyester-cotton blended Eli-Twist and TFO yarns. With the increase both in linear density and polyester content in fibre mix, there is a significant reduction in the permanent deformation and increase in the immediate elastic recovery. The linear density does not have any significant effect on delayed elastic recovery. The delayed elastic recovery initially increases and after certain level again decreases with reduction in polyester content. As compared to Eli-Twist yarns, TFO yarns are better in both immediate elastic recovery and delayed elastic recovery. Higher amplitude of extension reduces the immediate and delayed elastic recovery.

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